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COMMENTS ON ION SATURATION CHARACTERISTIC OF LANGMUIR PROBE AND DETERMINATION OF PLASMA POTENTIAL

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In order to determine the ion density from the ion saturation characteristic of a Langmuir Probe, one must, needless to say, employ the correct equation. There is, unfortunately, not only one equation but a multiplicity of equations corresponding to different plasma regimes. In low density plasmas, however, there are several regimes of interest wherein the ion saturation characteristic has the analytical form

$$I = kV_p^n = k(V - V_{po})^n \tag{1}$$

Where I is the ion current; k is a constant of the experiment; V_p is the potential of the probe with respect to "plasma potential"; V is the <u>measured</u> potential, with respect to an arbitrary reference, V_o; V_{po} is the "plasma potential" with respect to V_o; and n is a constant over the particular regime for which equation (1) is defined.

In their original work, Langmuir and Mott-Smith (1) derived an equation of the form expressed above with n equal to 1/2, for the case of a small cylindrical probe immersed in a collisionless plasma assuming the space charge effects in the probe sheath to be negligible. Extending the work of Langmuir and Mott-Smith to include the space charge effects in the sheath, Schulz and Brown (2,3) obtained n equal to 0.555 and 0.633 for no collisions, and one collision in the sheath,

respectively. Experimental observation of these three regimes has been reported in the literature (2,3,4).

Before one can employ the appropriate equation one must determine V_{po} and the value of n which is applicable for the conditions measured. One method is to plot $I^{1/n}$ vs. V for all appropriate values of n, as illustrated in the figure for a typical low-density plasma measurement. That value of n is correct for which the plot of $I^{1/n}$ vs. V is a straight line in the ion saturation region (curve "a" in fig. 1). Extending the straight line region to $I = 0$, we note from equation (1)

$$V = V_{po} \tag{2}$$

While this method will give reasonable results, it is very laborious and is not amenable to machine solution.

A simplified method, amenable to machine solution, is based on the observation that $\frac{d \ln I}{d \ln V}$ is dependent upon the origin of V. From eq. (1) we see that

$$n = \frac{d \ln I}{d \ln V_p} = V_p \frac{d \ln I}{dV} = \left(\frac{V_p}{V}\right) \frac{d \ln I}{d \ln V} = \left(\frac{V_p}{V}\right) n' \tag{3}$$

$$n' = \frac{d \ln I}{d \ln V} = \frac{V}{I} \frac{dI}{dV} \tag{4}$$

$$\frac{n}{n'} = \left(\frac{V_p}{V}\right) \tag{5}$$

$$V_{po} = V - V_p = V\left(1 - \frac{n}{n'}\right) \tag{6}$$

In practice, one programs the machine to obtain n', and then V_{po} for all likely values of n. That n (and V_{po}) is correct for which

V_{po} is constant over a potential range. An example is presented in the following table:

V,* volts	I,* μa	V_{po}		V,* volts	I,* μa	V_{po}	
		n = 0.555	n = 0.633			n = 0.555	n = 0.633
15	5.11	14		70	9.32	--	15
20	5.58	14		75	9.66	--	14
25	6.02	14		80	10.00		13
30	6.44	14		85	10.33		13
35	6.84	15		90	10.66		14
40	7.20	17	--	95	10.98		14
45	7.73	14	--	100	11.30		14
50	7.91	12	20	105	11.61		14
55	8.26	10	18	110	11.91		14
60	8.61	9	17	115	12.21		14
65	8.97	8	16	120	12.51		14
				125	12.80		14

*D.C. Discharge argon 275μ Hg; 45 ma discharge current.

The table indicates that the plasma potential, V_{po}, is 14 volts, and that the exponent in the region from 15 to 45 volts is 0.555, and 0.633 in the region beginning at 75 volts and extending to higher potentials. The apparent low accuracy in the determination of V_{po} is a result of employing an X-Y recorder to record the data. Digital equipment should greatly improve the obtainable accuracy.

The procedure described is particularly applicable when the plasma potential cannot be obtained from the electron current characteristic. This situation exists when the electron current at plasma potential is so high as to burn out the probe, and/or disturb the plasma.

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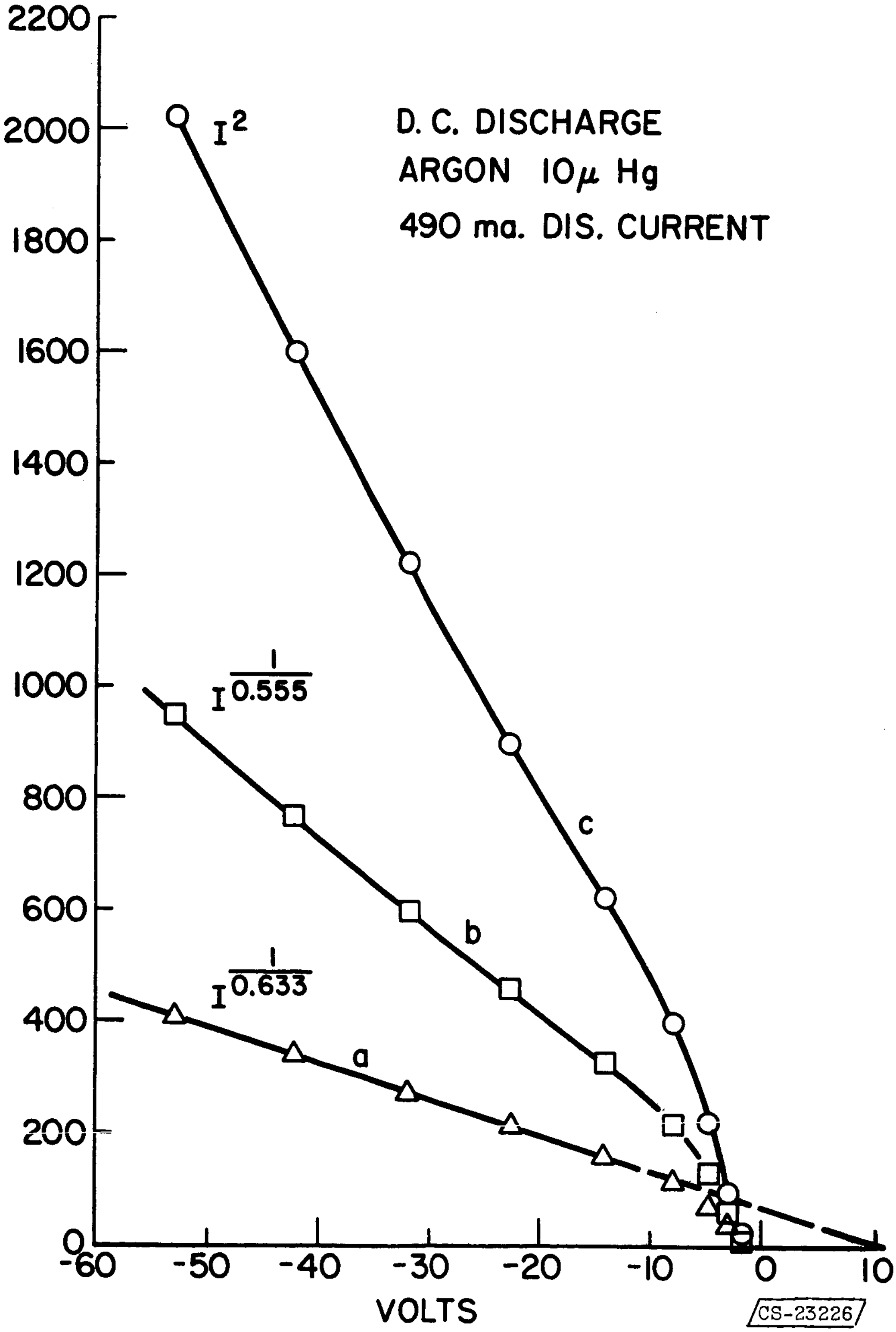

Fig. 1. Plot of $I^{\frac{1}{n}}$ vs V for n = .500, .555, .633.